



REGIONE AUTONOMA DE SARDIGNA
REGIONE AUTONOMA DELLA SARDEGNA

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Fondo per lo Sviluppo
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GWADW
Online 2021

The Sar-Grav Laboratory



D. D'Urso on behalf of the Sar-Grav Team



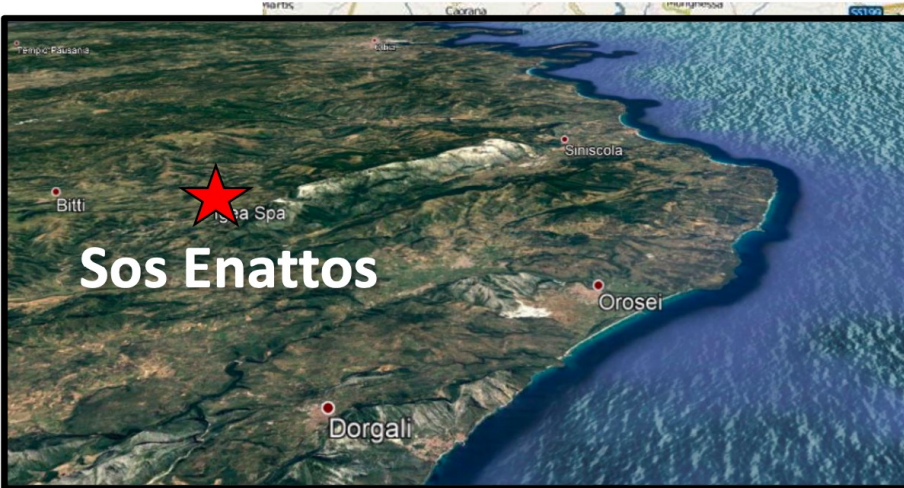
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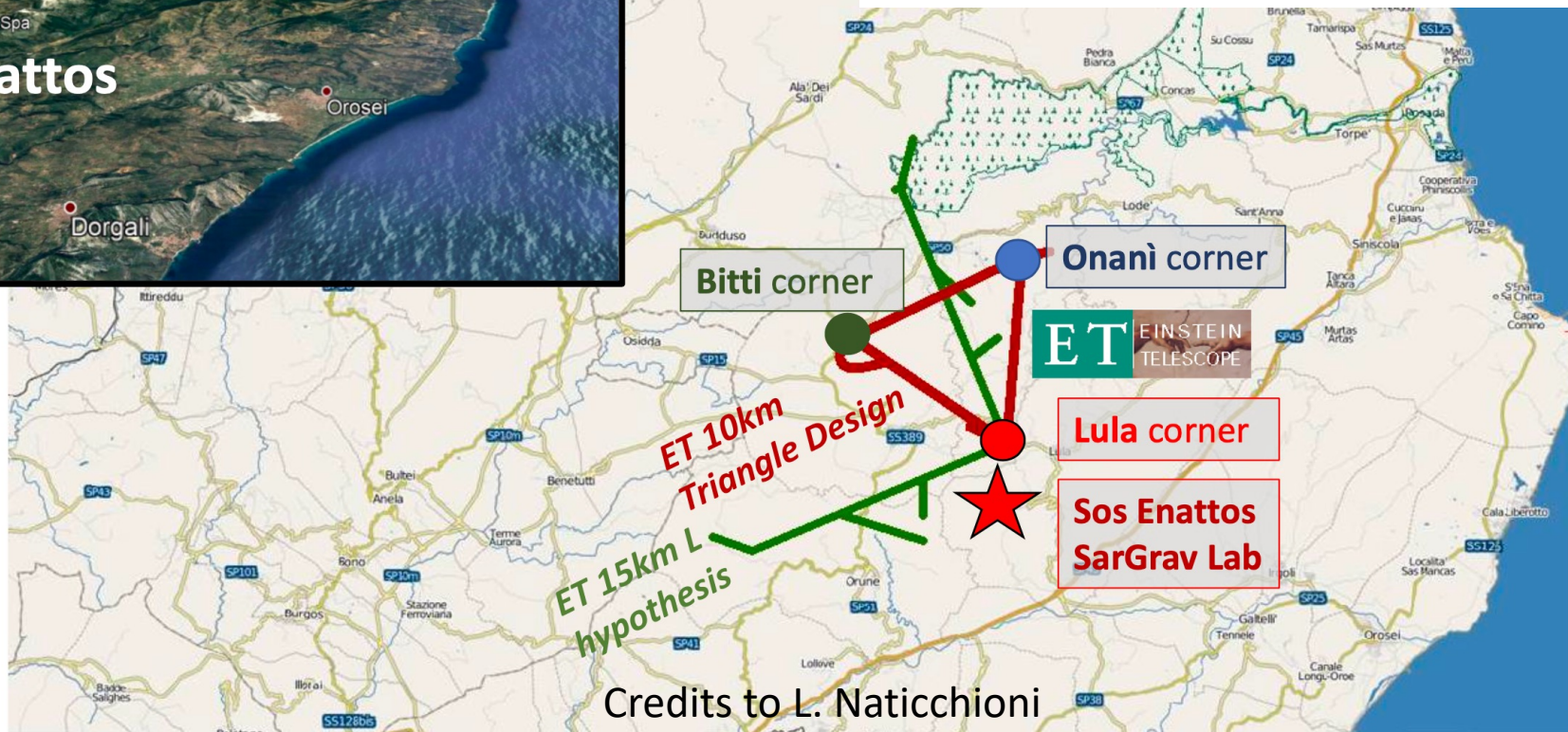
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Sos Enattos Site for ET



Former mine with underground access guaranteed through tunnels and shaft



Credits to L. Naticchioni



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The SarGrav Laboratory

Founded with 3.5 M€ by the Regione Autonoma della Sardegna (RAS) to host low seismic noise underground experiments (low seismic noise experiments, cryogenic payloads, low frequency and cryogenic sensor development)

- ~ 900 m² surface Laboratory
- 3 Underground stations equipped for measurements at different depths
- ~ 50 m² underground area available
- planned a 250 m² underground Lab
- First experiment: Archimedes (founded by INFN)





Sar-Grav Management Structure

Executive Board (EB)

- ✓ M. Carpinelli (Chair), UniSS delegate
- ✓ S. Falciano, INFN delegate
- ✓ G. Saccorotti, INGV delegate
- ✓ M. Caria, IGEA delegate
- ✓ 2 RAS delegates

Technical-Scientific Board (TSB)

- ✓ F. Ricci (Chair, La Sapienza University)
- ✓ G. Saccorotti (INGV)
- ✓ D. D'Urso (UniSS)
- ✓ 1 RAS delegate

Current Activities

- Experimental activities
- Underground Lab excavation
- Infrastructure enhancement
- Site monitoring and support for ET Site Characterization studies



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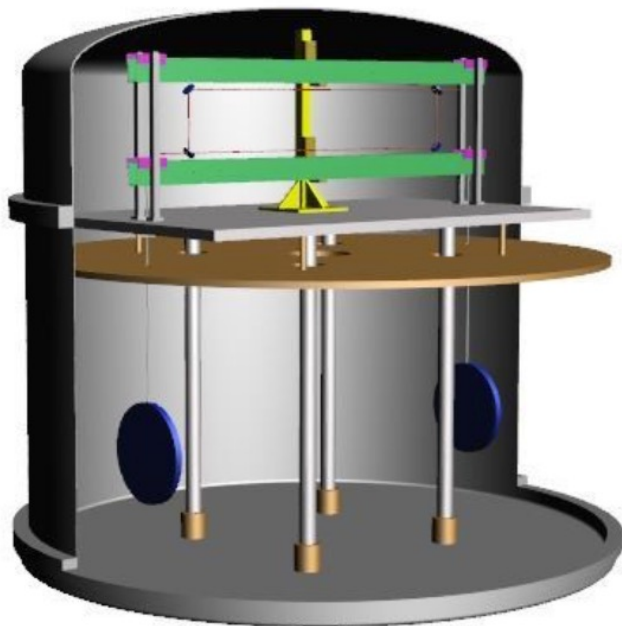


Experimental activities



First Experiment: Archimedes

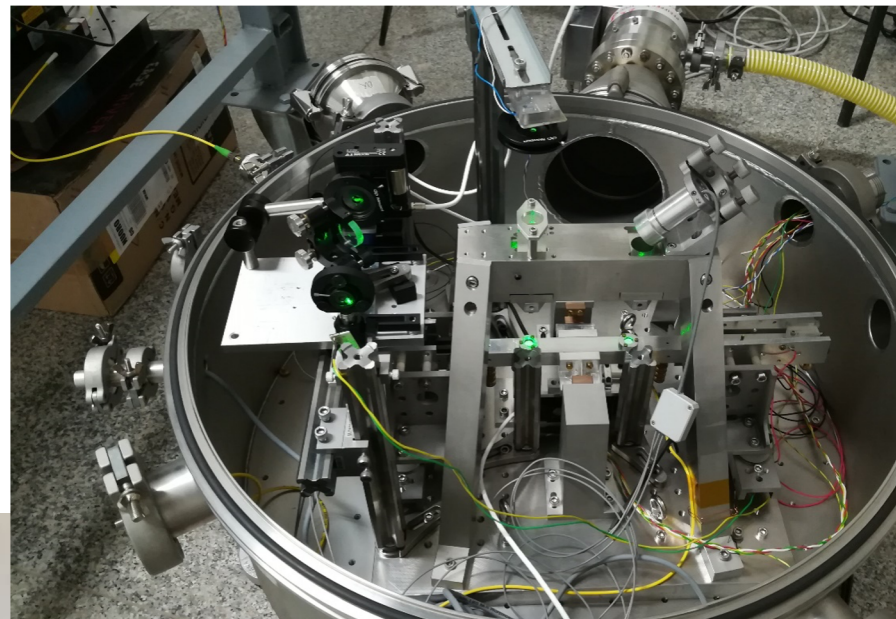
- Experimental Goal: measurement of the interaction between vacuum fluctuations with gravity weighting a Casimir multi-cavity while changing the reflectivity of its layers. A change in the reflectivity corresponds into a variation of the internal vacuum state energy.
- Apparatus: high sensitivity balance working in cryogenic conditions (~ 90 °K)



- High- T_c superconductors (i.e. YBCO) as natural Casimir multi-cavities;
- Measurements taken in HV (10^{-8} mbar) at cryogenic temperature ($T = T_c \approx 90$ K);
- Reflectivity changed via thermal actuation;
- Flexible thin joints with low thermal noise;
- Two suspended arms to apply coherent noise subtraction;
- Interferometric read-out system;
- Feedback control;
- Low seismic noise site.



Prototype Balance and Inner Cryostat installed @ Sos Enattos

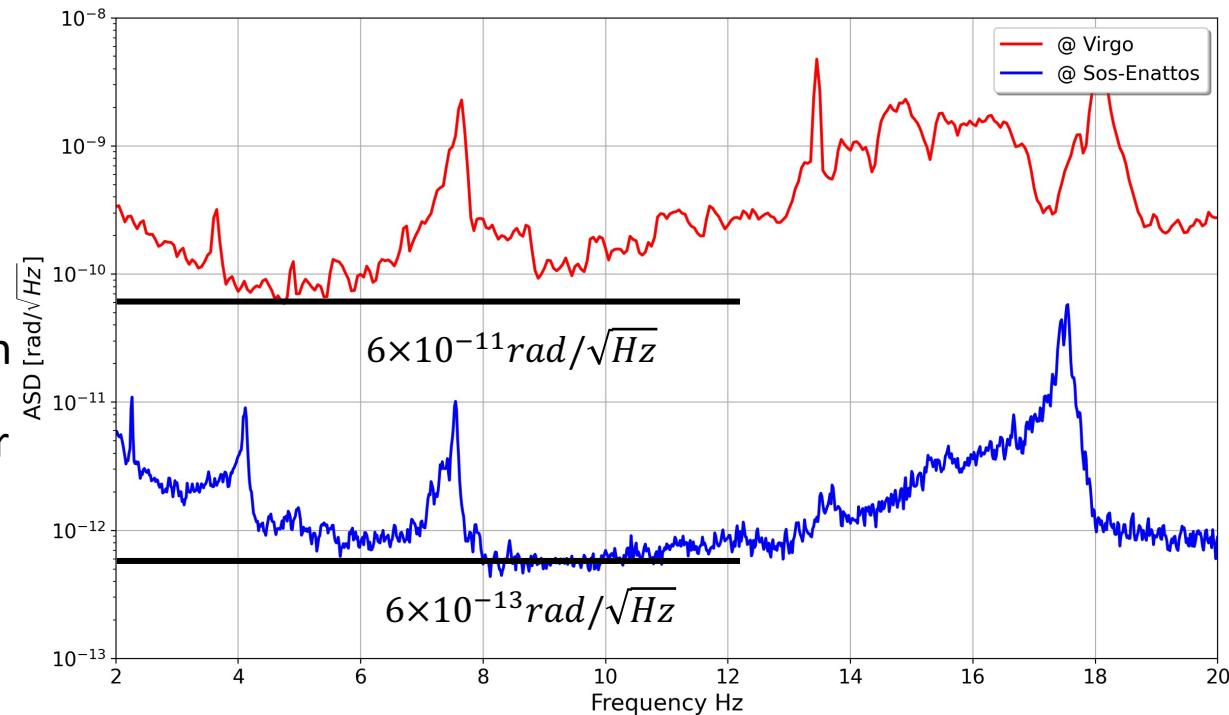


- Prototype test at lower frequencies (June 2021)
- Shipping and installation of the final balance (June – July 2021)



ARCHIMEDES for ET: the tiltmeter

- Quality check of the site with a fundamental physics experiment
- Direct tilt measurement from 2 Hz to 20 Hz (region of interest for ET): best sensitivity in the world for a tiltmeter in the region 2 Hz – 20 Hz (paper in preparation)
- At our knowledge Sos Enattos has shown the lowest tilt noise ever measured





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Underground Lab Excavation



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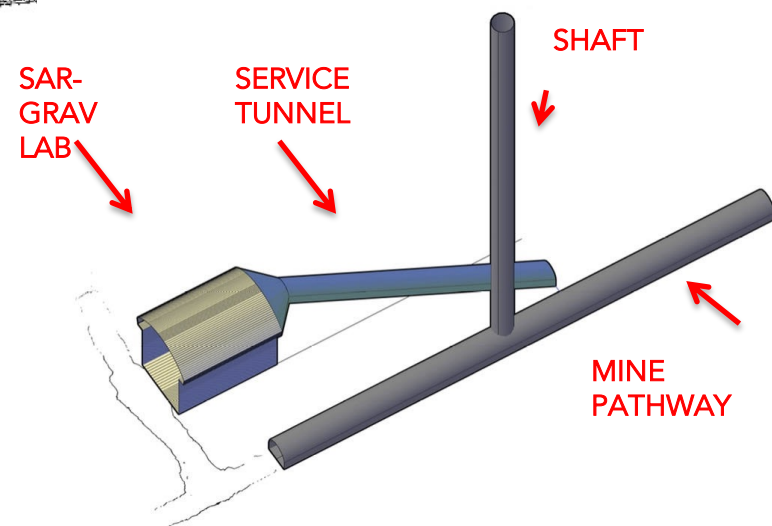
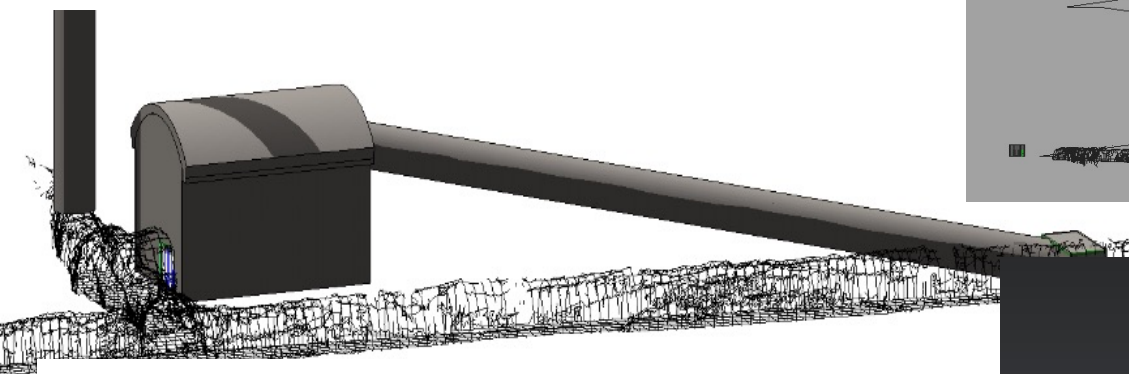
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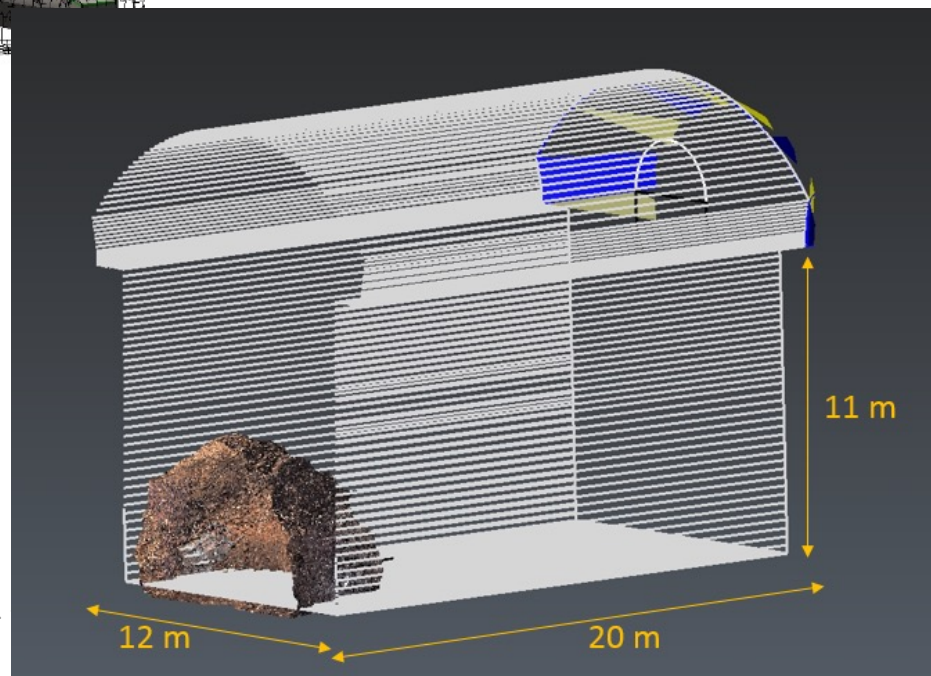
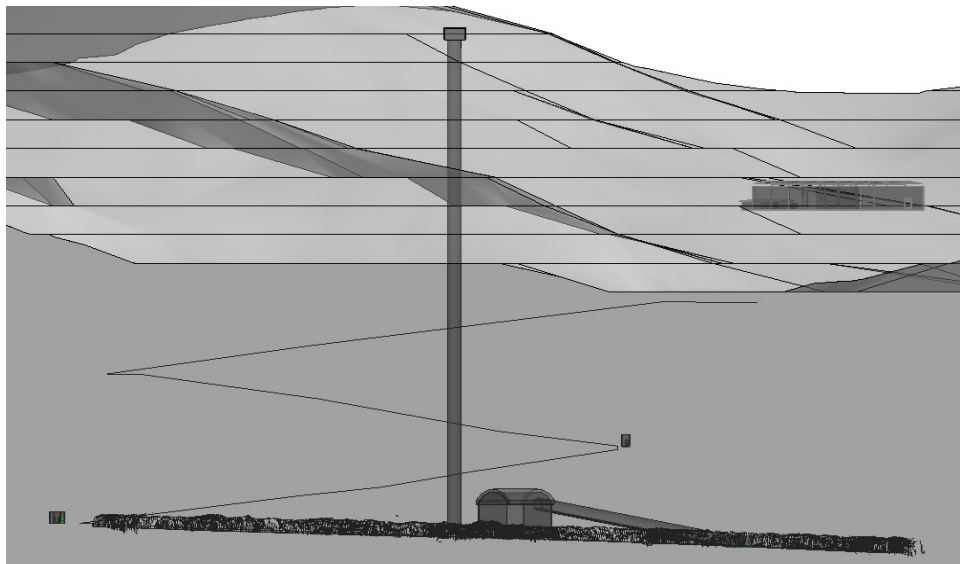
Underground 3D model

See talk by **M. Marsella**

Session “Third Generation Infrastructures”



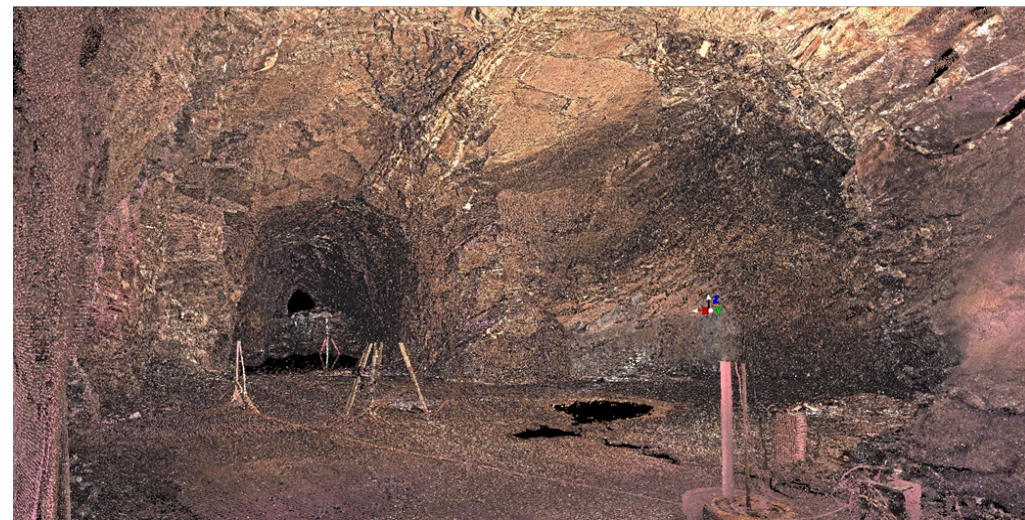
- GWADW 21



The feasibility study preceding the final design has been completed

- 3D modelling
- Rock characterization analysis
- Modelling of the excavation and consolidation phases
- Geometry of lab and service areas have been defined
- Technological and safety infrastructures have been defined

Next step: Start of the procedure for contracting the construction





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Infrastructure Enhancement



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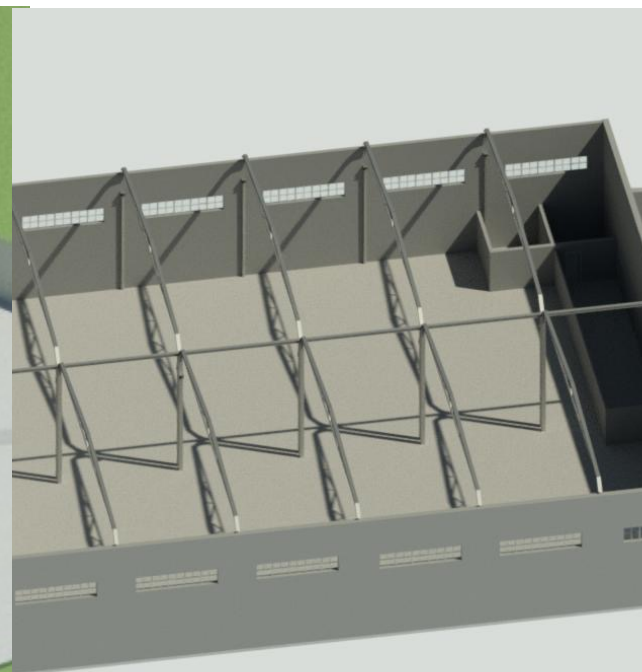
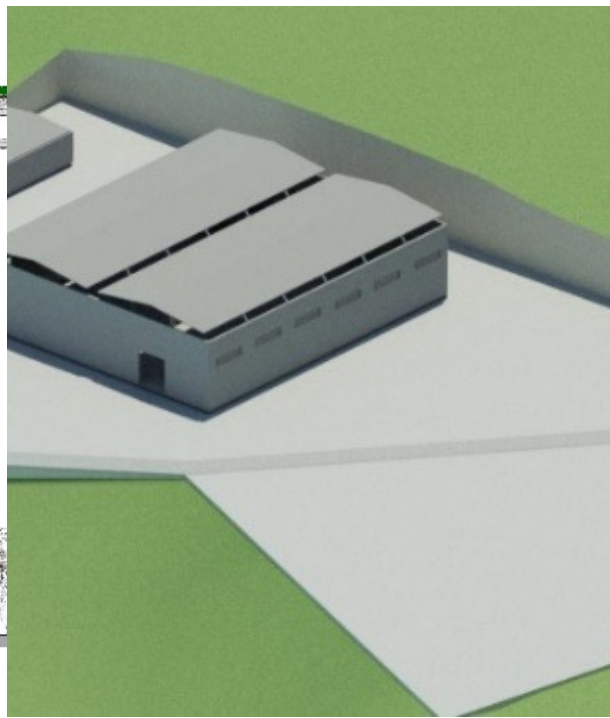
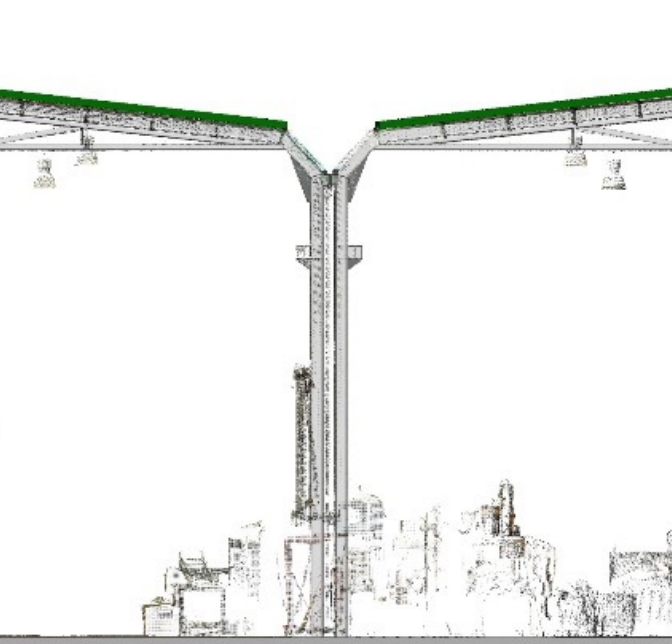


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Surface Laboratory

- 3D model
- Structural studies
- Optimization of space



Infrastructure Enhancement

- A plan to equip Sar-Grav lab with additional facilities by the 2021 has been already founded by the RAS
 - ✓ Mechanic Lab equipped with a 20 tons crane
 - ✓ Clean Room
 - ✓ Data storing and management system
 - ✓ Nitrogen liquefier
 - ✓ Fiber network link (1 Gbps)
- Additional small underground area for experiments, equipped with power, gps and fiber link, will be set up

FC

- FE





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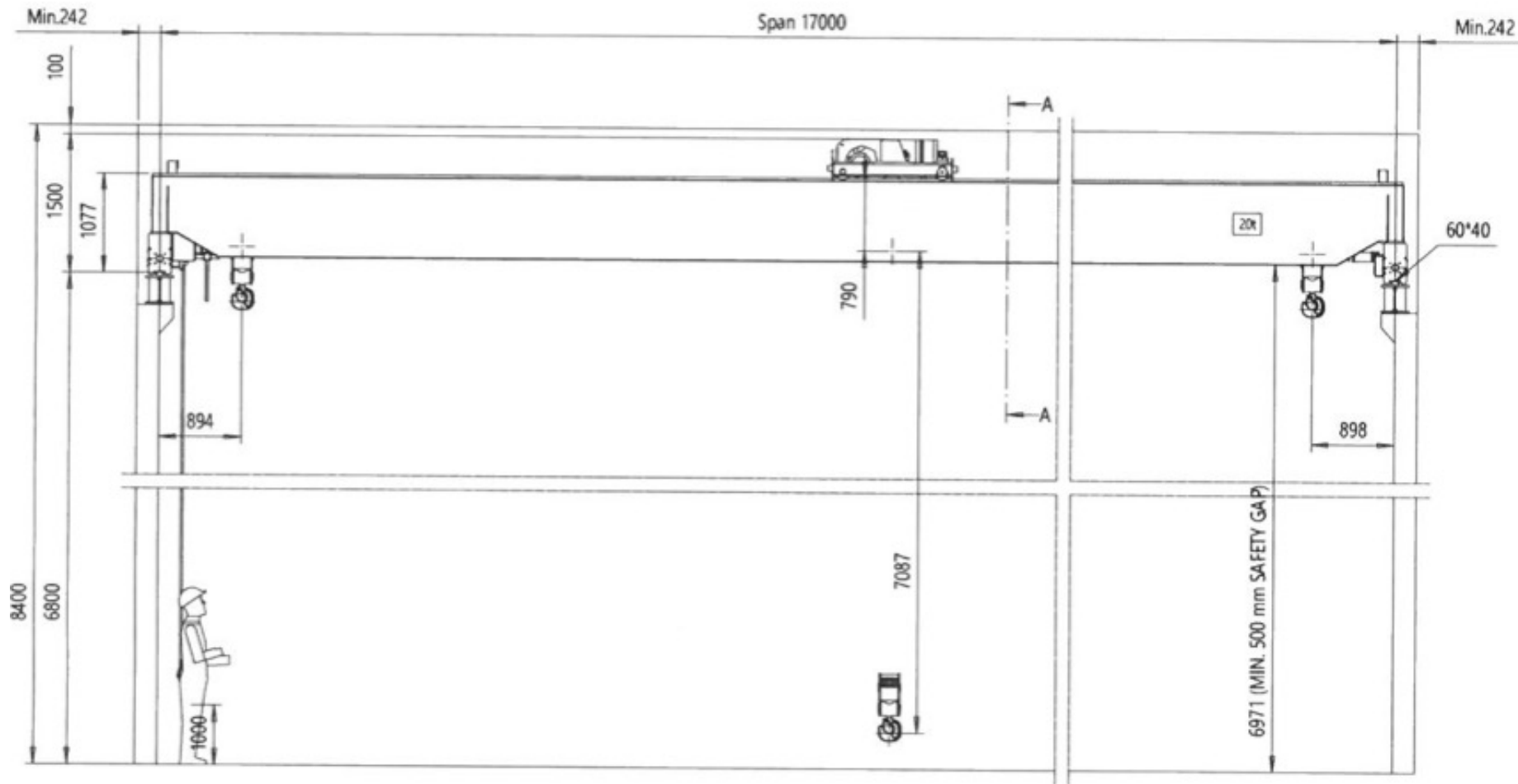
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20 t Crane





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Work already on going

**New Experimental
area in preparation**



D.



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Site monitoring and support for ET Site Characterization studies



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Site monitoring and characterization

See talk by **L. Naticchioni**

Session “Third Generation Infrastructures”

- Measurement stations
 - ✓ SarGrav surface Lab
 - ✓ SOE0 (surface)
 - ✓ SOE1, SOE2, SOE3 (-86 m, -111 m, -160 m)
- Sensors on site
 - ✓ 4 broadband triaxial seismometers;
 - ✓ 5 short-period triaxial seismometers (first *seed* of a new array);
 - ✓ 2 magnetometers (1 buried at surface, 1 underground);
 - ✓ High precision tiltmeter (Archimedes prototype)
 - ✓ Weather station
- New sensors expected to be installed in the next months (seismometers, geophones, microphones, magnetometers)
- Data acquired at the SarGrav control room, transmitted via UMTS link to remote server (INGV-PI server → ET repository), and accessible through an INFN access point.

Measurement stations

See talk by L. Naticchioni
Session "Third Generation Infrastructures"

Sos Enattos measurement stations (since Aug. 2020)

- SarGrav surface lab
- SOE0 (surface)
- SOE1, SOE2, SOE3
(-84m, -111m, -160m)



SarGrav surface lab



- integrated into the INGV
seismometer network

<http://cnt.rm.ingv.it/en/instruments/station/SENA>



SOE1
STAZIONE
SOE 1

SOE2 / SENA

STAZIONE
SOE 2

SarGrav Lab excavation zone

SOE0 (surf.)

SOE3
STAZIONE
SOE 3

Site Characterization and monitoring

- Long-term seismic and environmental monitoring
- First year of seismic characterization measurements at Sos Enattos published
 - ✓ **JPCS** 1468, 2020 <https://doi:10.1088/1742-6596/1468/1/012242>
 - ✓ **SRL** 2020, <https://doi.org/10.1785/0220200186>,
 - ✓ **EPJP** 2021, <https://doi.org/10.1140/epjp/s13360-021-01450-8>
- In the 1-10Hz is among the quietest sites in the world
- Very low environmental noise



Conclusions and perspectives

- SarGrav Lab is a very low noise infrastructures, designed to host low seismic noise experiments, cryogenic payloads, low frequency and cryogenic sensor development
- The Archimedes use case will allow assess the site quality and to verify how to implement underground cryogenic and vacuum systems without degrading the site
- Experimental activities:
 - ✓ preliminary experimental tests to assembly Archimedes components

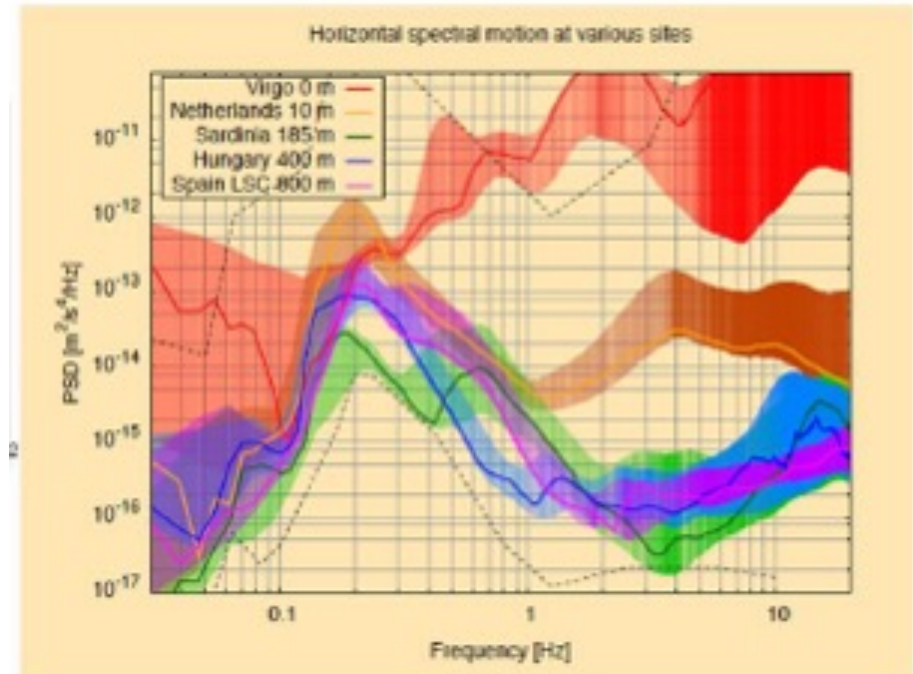
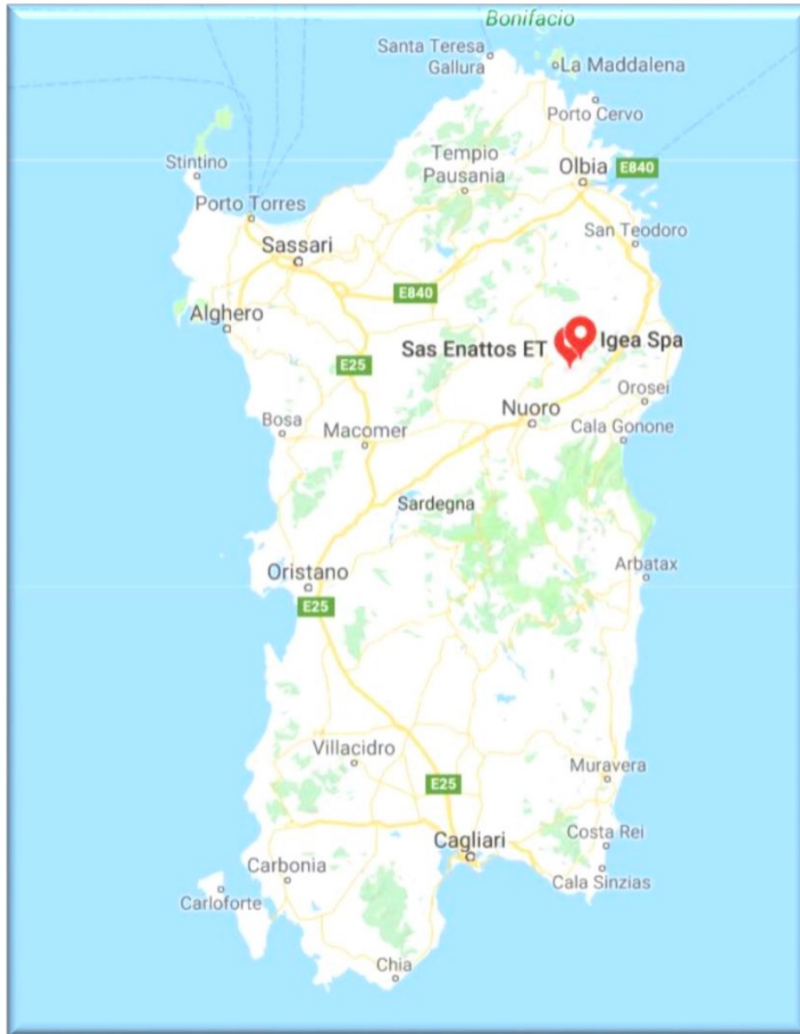
Conclusions and perspectives (2)

- Underground excavation
 - ✓ feasibility study preceding the final design completed
- Enhancement plan of surface infrastructures
- Site Monitoring: synergy with ET Characterization Activities and support in terms of logistics and manpower
- SarGrav Lab will host ET technology prototypes to test them in the same ET expected noise conditions

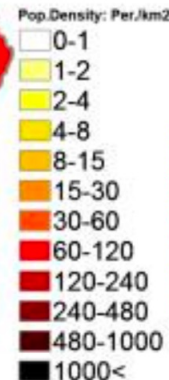
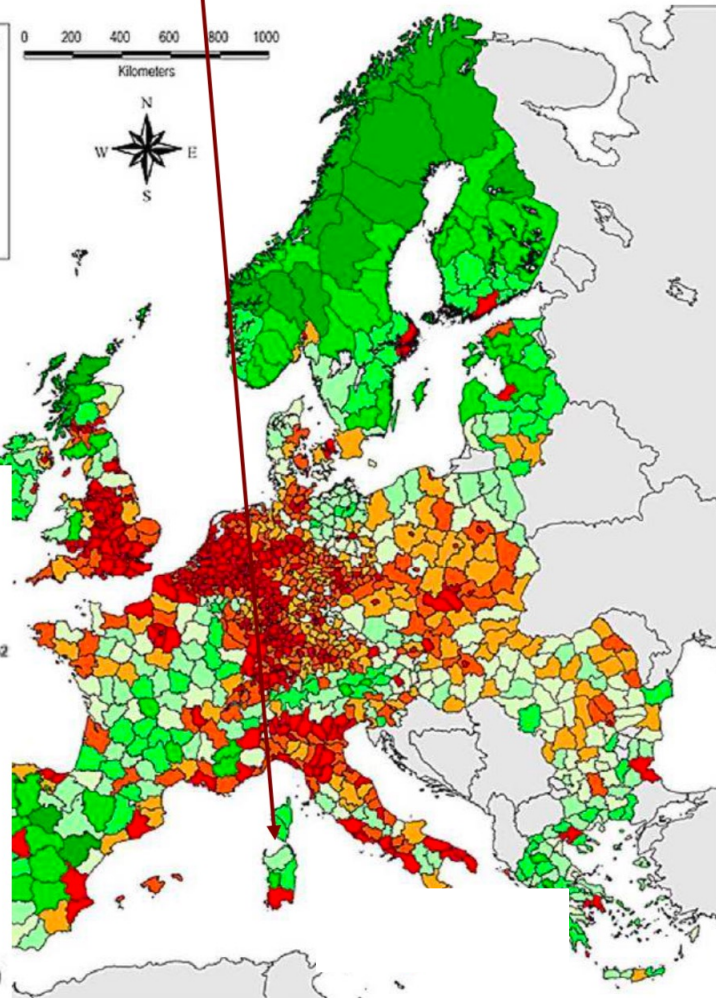
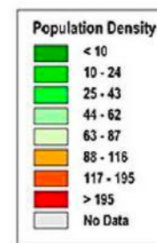
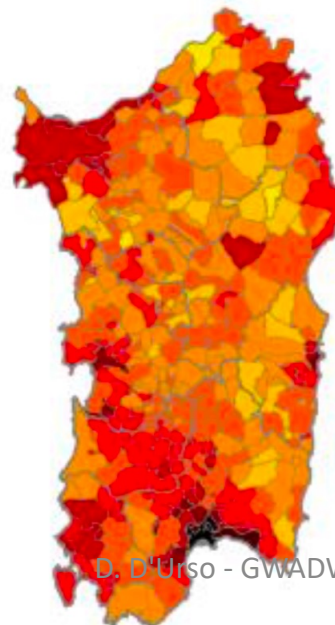
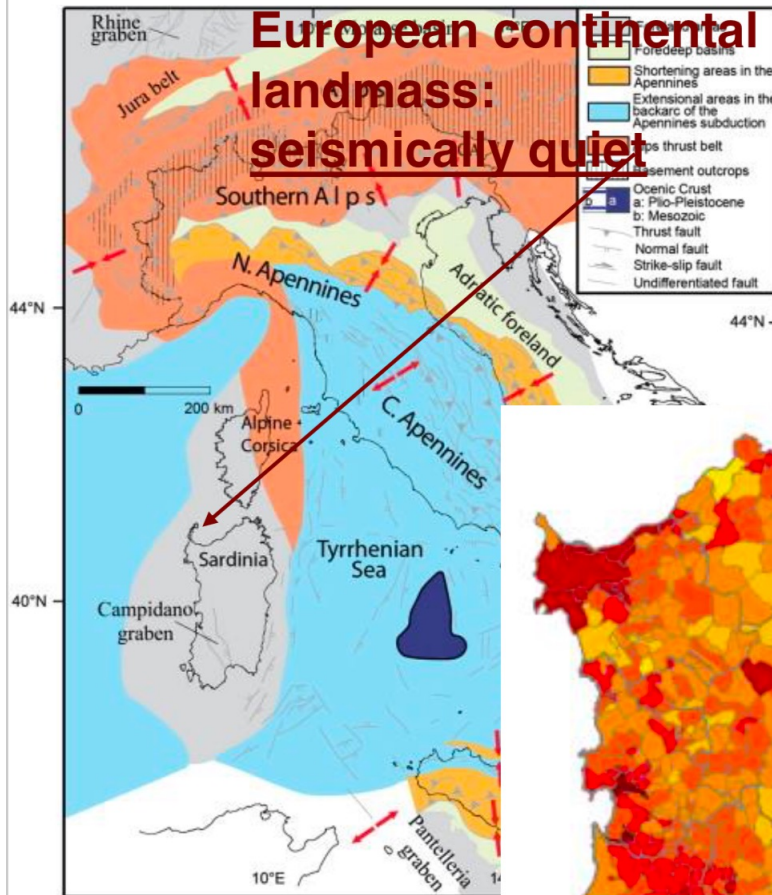


See you soon in Sardinia

Low Seismic Noise Site



One of the least populated areas in EU

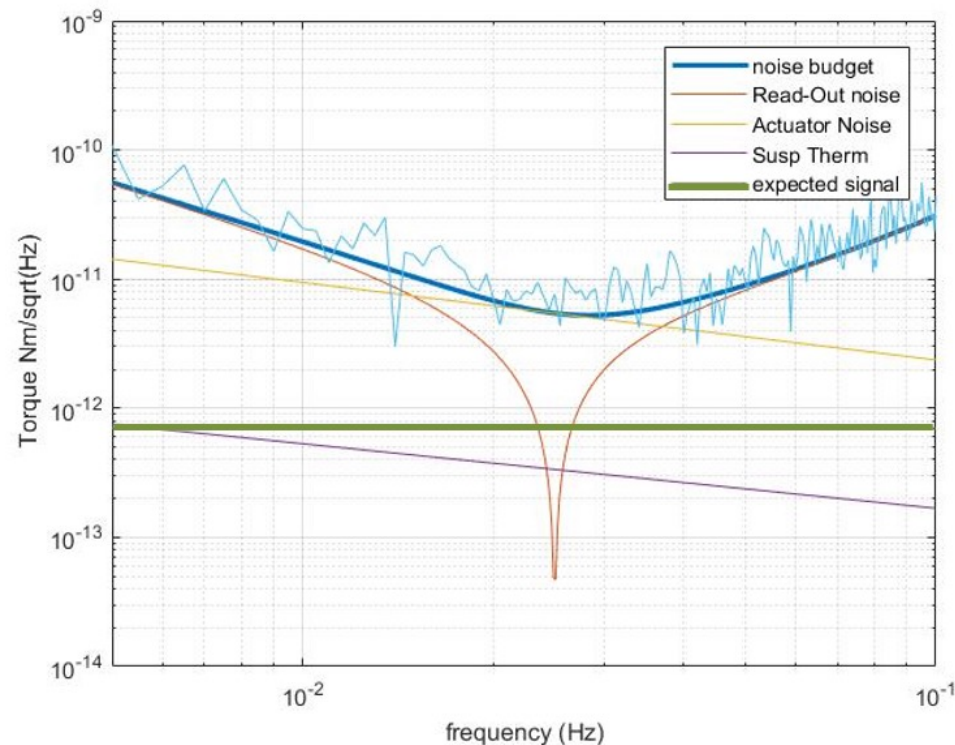




Prototype @ low frequency

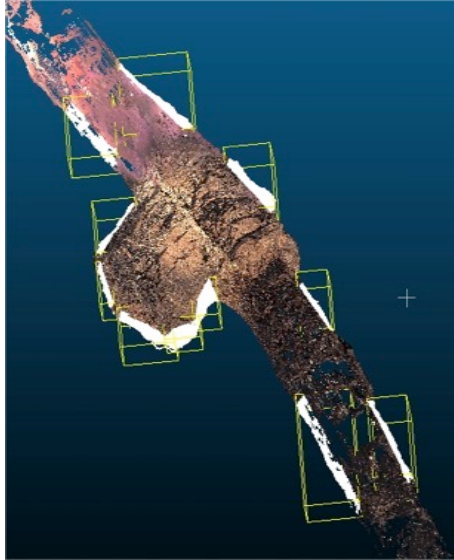
Commissioning on June 2021

- Diffused light
- Substitution of actuator power supplies
- Software optimization for low frequency control
- Installation of vacuum valve to operate without pump noise (from EGO Vacuum group)



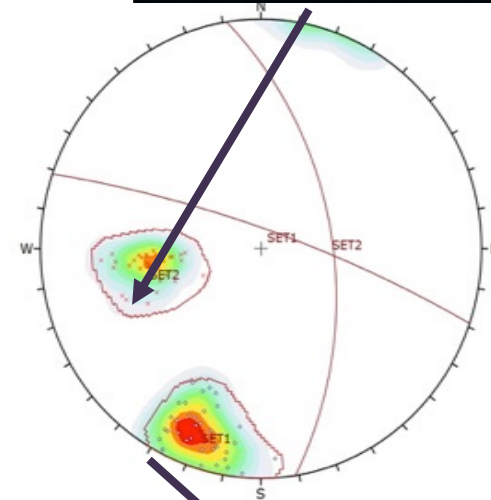
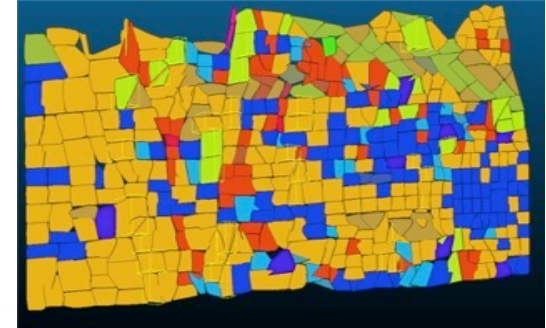
Low frequency sensitivity obtained @EGO

Laser scanning for geo-structural surveying



- ❑ Rock discontinuities identified by the dense laser point cloud
- ❑ Laser scans at different orientations and position along the galleries

Laser scanning for geo-structural surveying



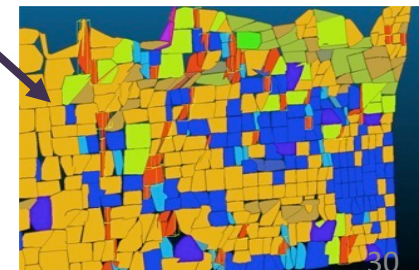
Symbol	SET	Quantity
+	1	36
+	2	31

Color	Density Concentrations
0.00	- 2.20
2.20	- 4.40
4.40	- 6.60
6.60	- 8.80
8.80	- 11.00
11.00	- 13.20
13.20	- 15.40
15.40	- 17.60
17.60	- 19.80
19.80	- 22.00

Maximum Density	21.77%
Contour Data	Plot Vectors
Contour Distribution	Color
Counting Circle Size	1.0%

Plot Mode	Plot Vectors
Vector Count	67 (67 Entries)
Hemisphere	Lower
Projection	Equal Angle

- ☐ segmentation
- ☐ Semi automatic (supervised) plane extraction
- ☐ Set parameters for rock kinematic stability analysis





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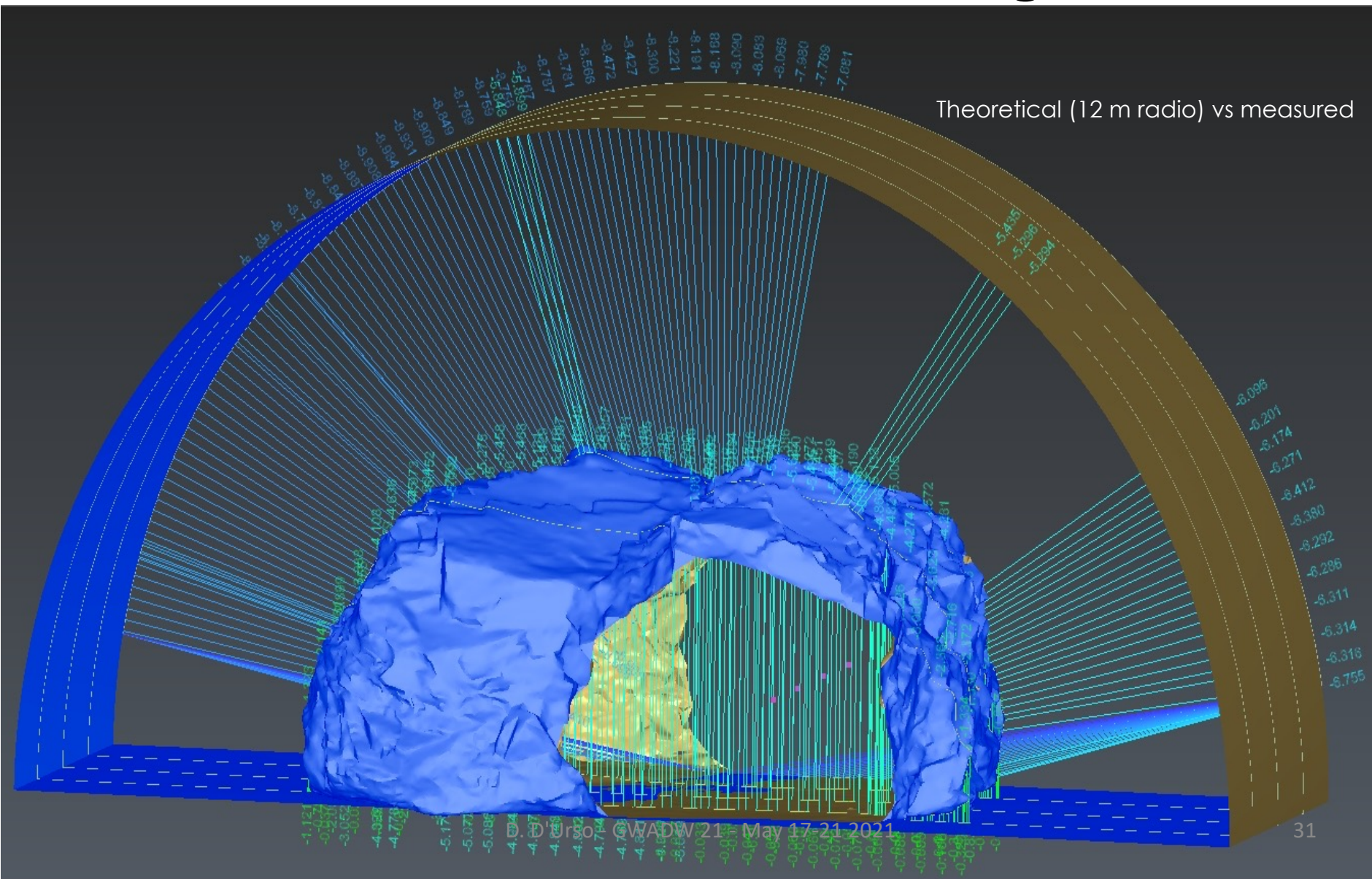
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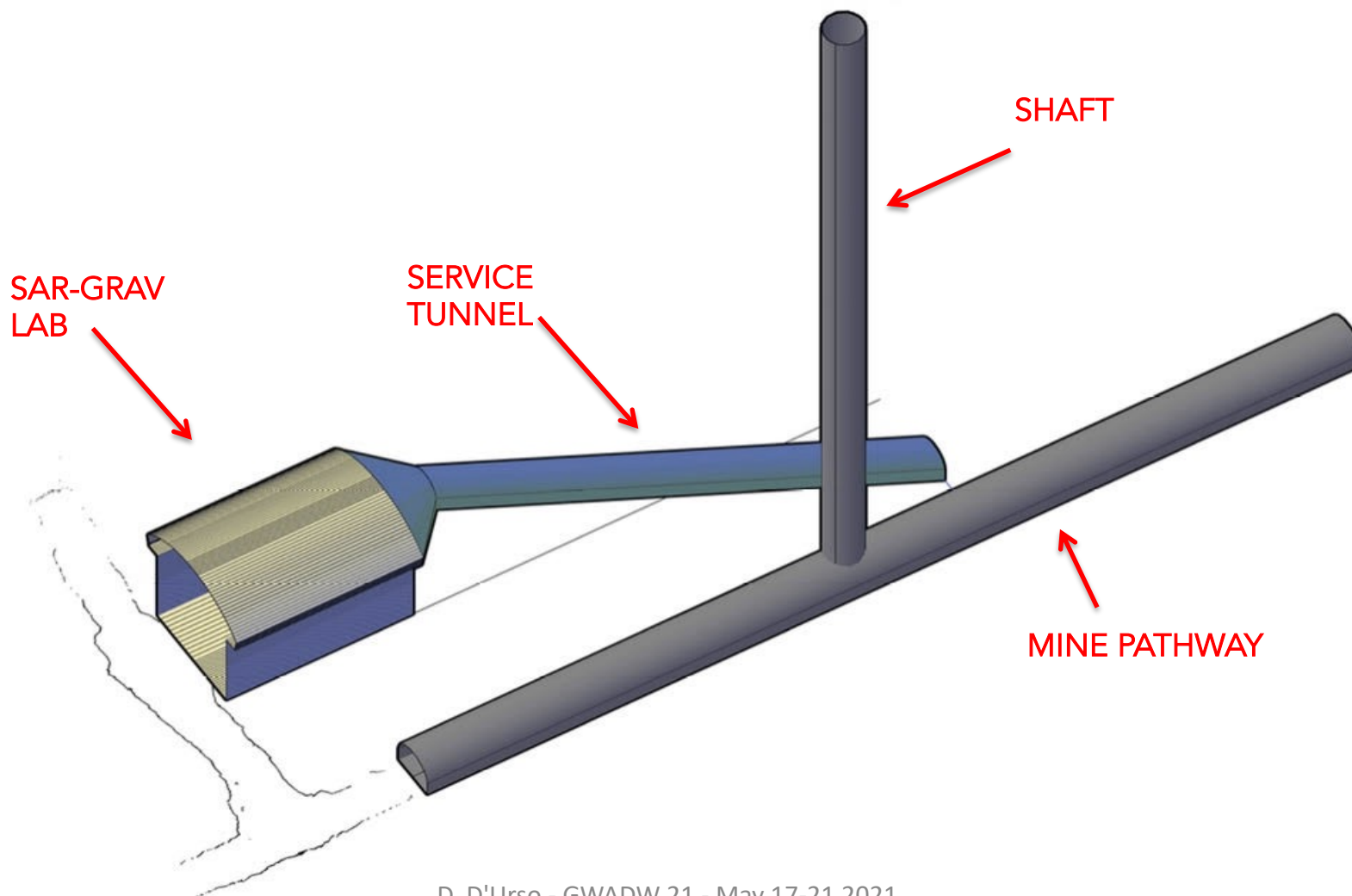
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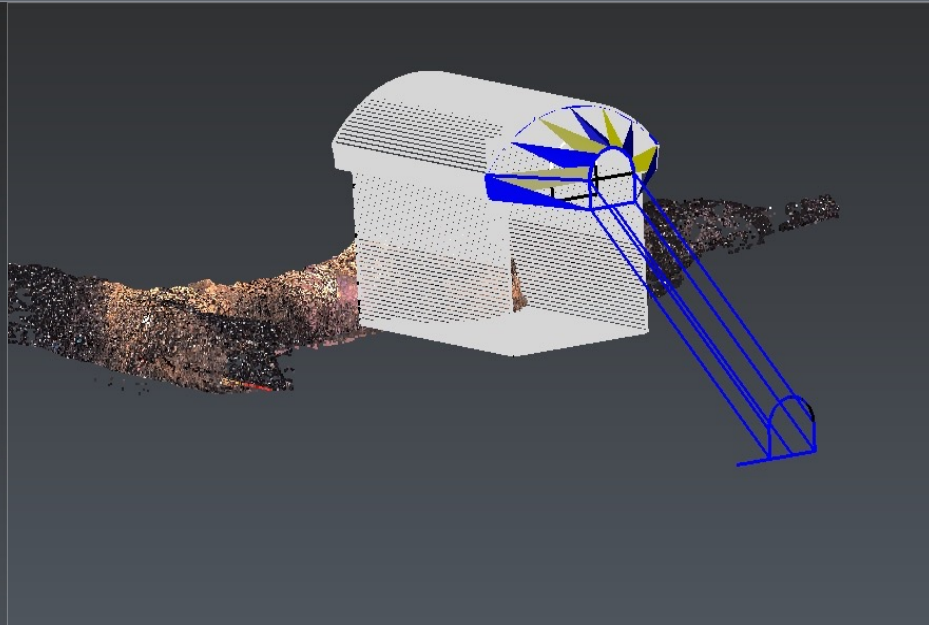
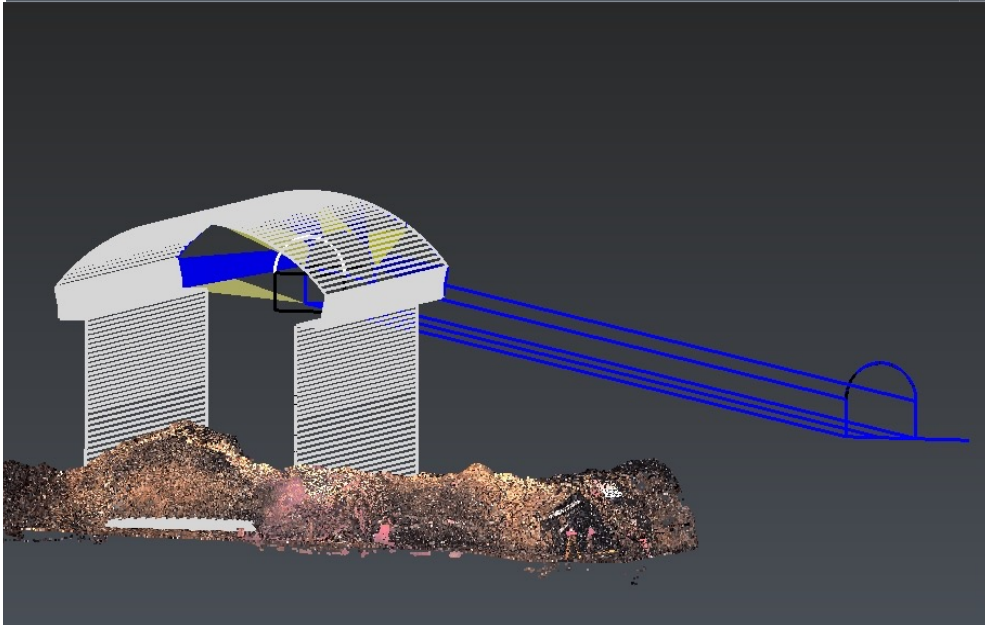
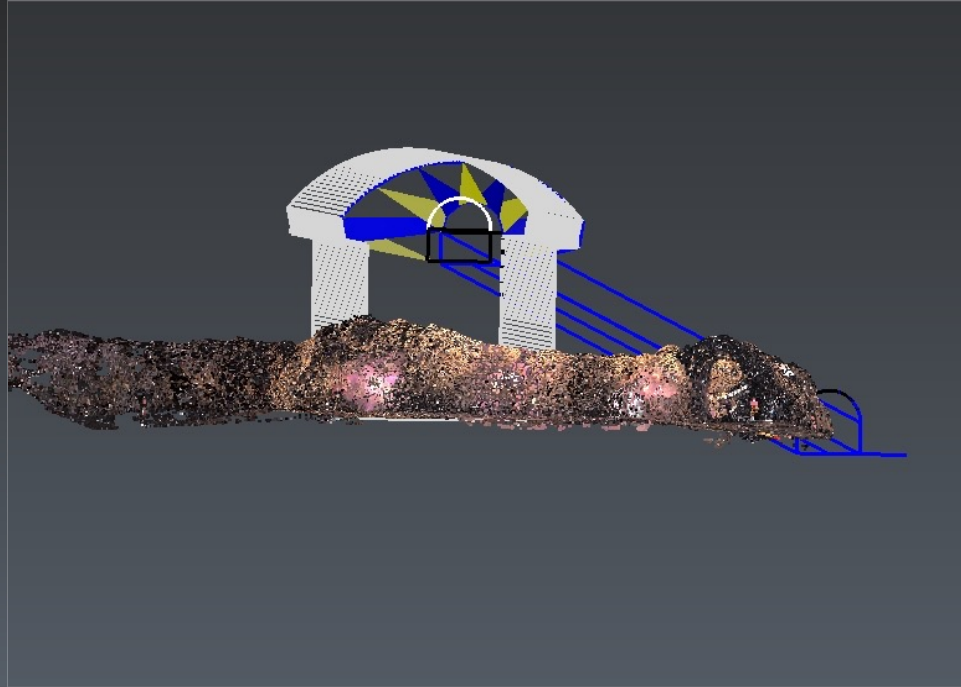
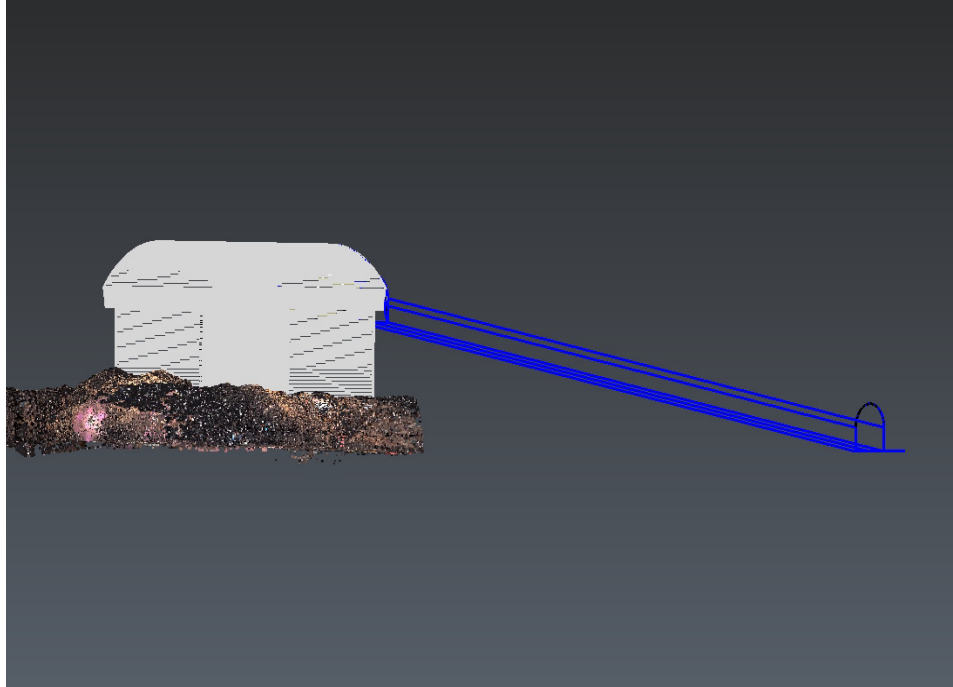


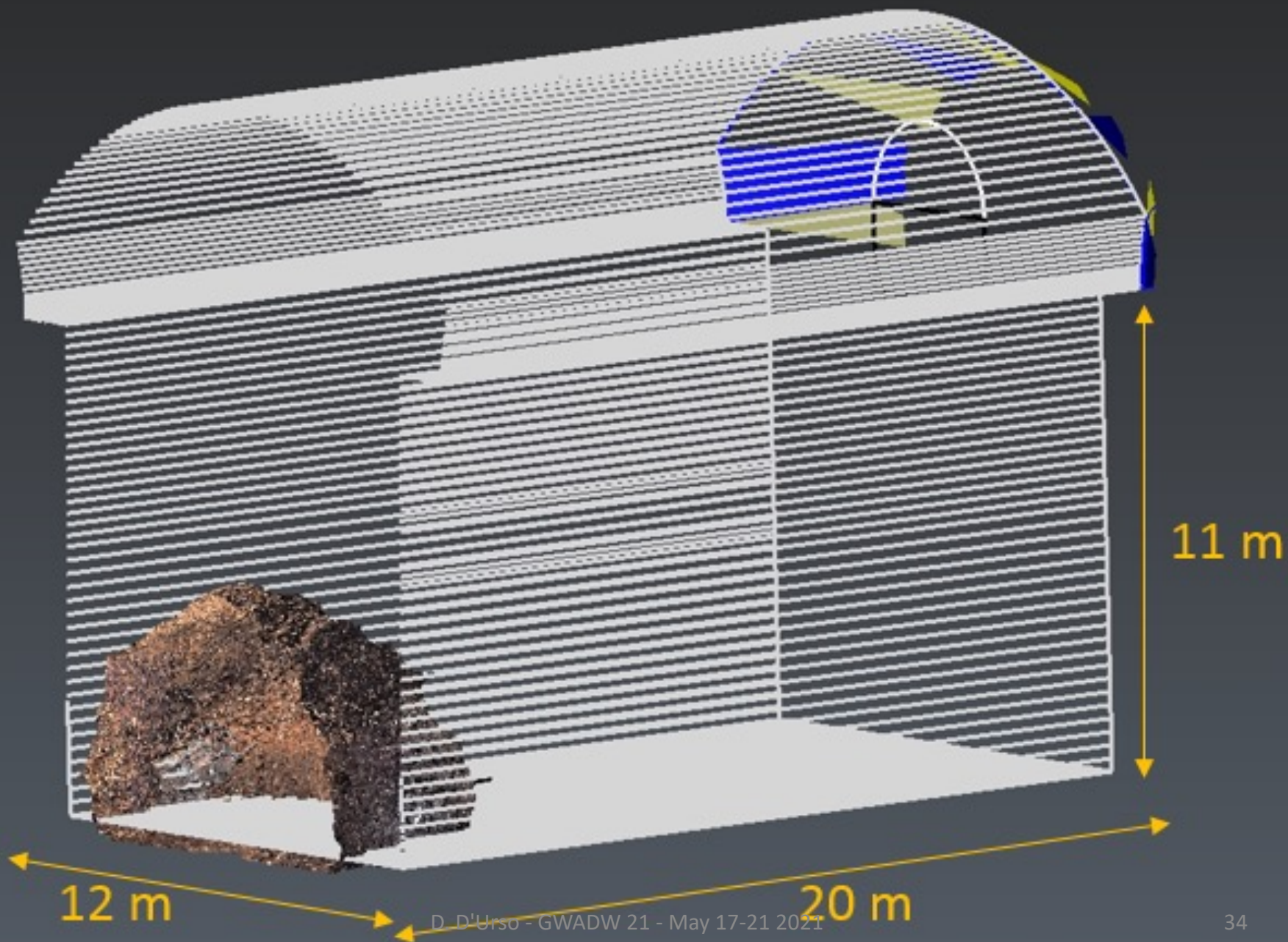
Toward the cavern design

Theoretical (12 m radius) vs measured









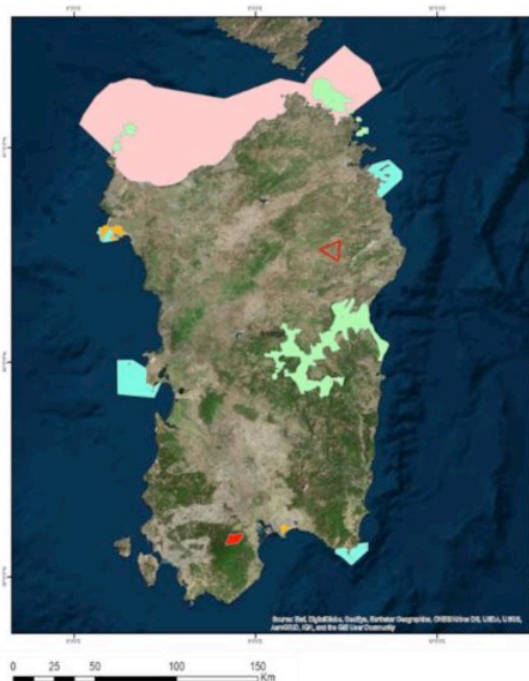


Interference Analysis

A.Paoli @ 10th ET symposium

INTERFERENCE ANALYSIS

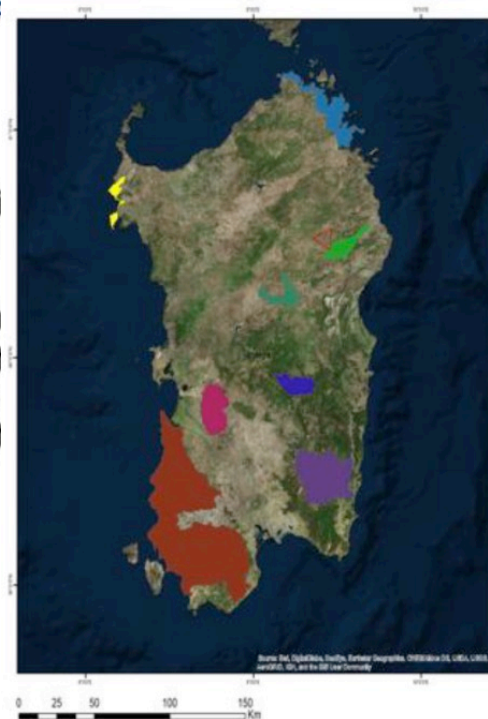
Protected areas – Regional and National Parks



- ET
- Parchi naturali nazionali
 - Parchi naturali regionali
 - Riserve naturali statali
 - Riserve naturali regionali
 - Altre aree naturali protette
 - Riserve Naturali Marine
 - Altre aree naturali protette

INTERFERENCE ANALYSIS

Geo-Mining Parks

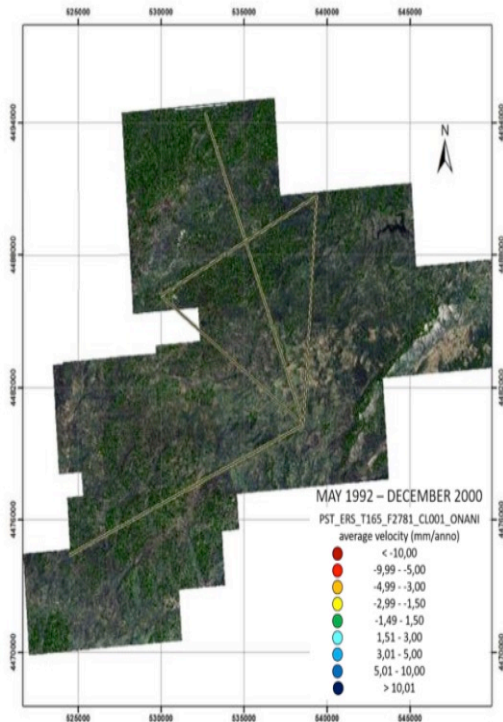


- ET
- Parco Geominerario Ambientale Storico**
- nome
- ARGENTIERA NURRA
 - FUNTANA RAMINOSA
 - GALLURA
 - GUZZURRA - SOS ENATTOS
 - MONTE ARCI
 - ORANI
 - SERRABUS - GERGEI
 - SULCIS - IGLESIENTE - GUSPINESE

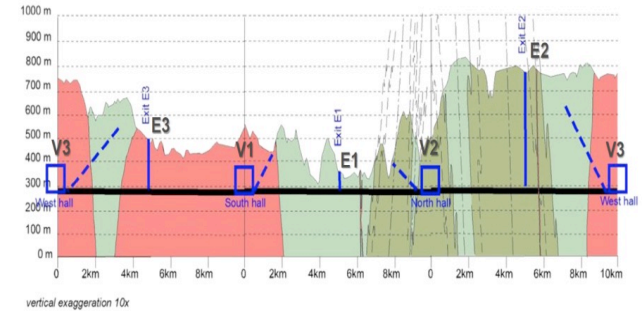
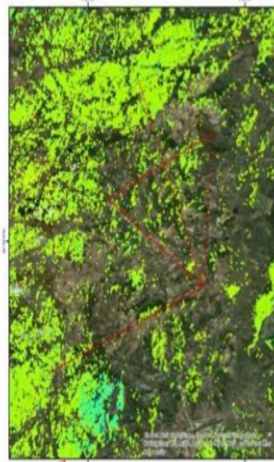
Sos Enattos site qualification

A.Paoli @ 10th ET symposium

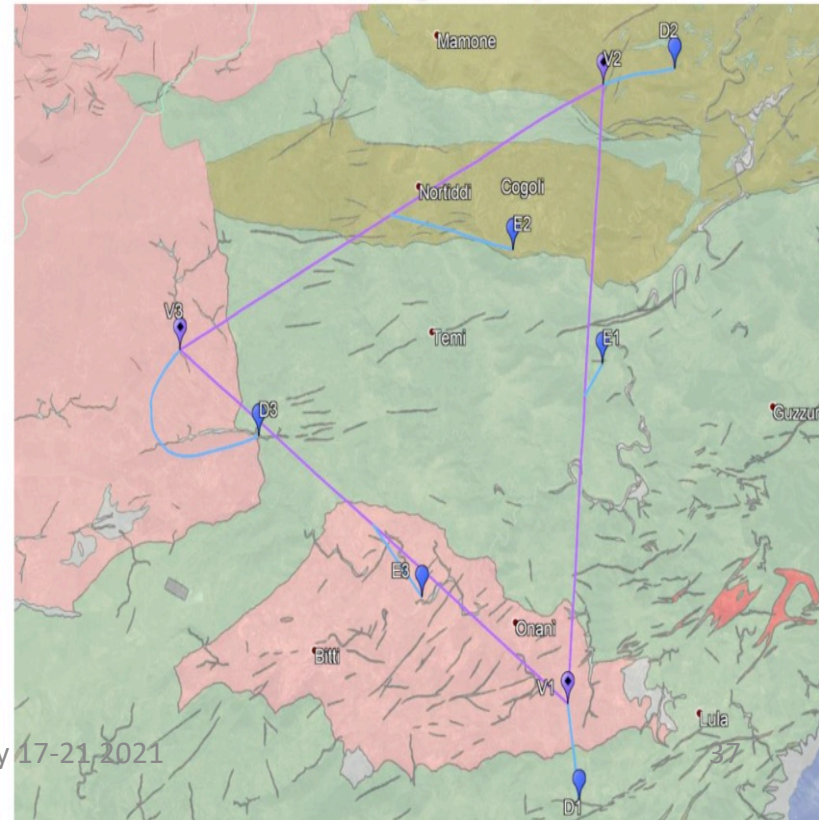
Crustal Deformation and Ground Motion DInSAR Analysis



- Very stable geodynamic setting
- No evidence of ground settlements due to local factors
- Link to the Space Geodesy Center in South Sardinia for reference frame issues



Geological Map





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Fondata nel 1562

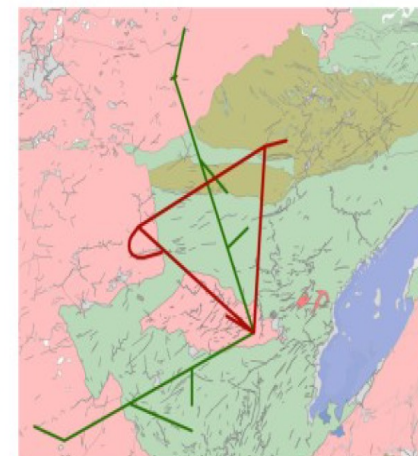
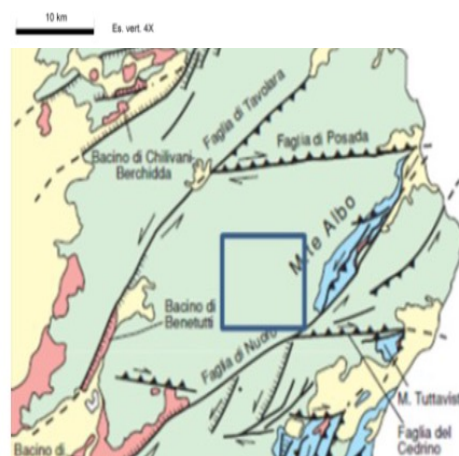
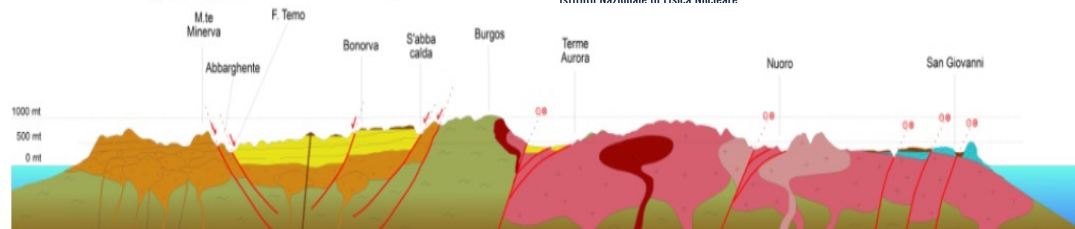
Dipartimento di Chimica e Farmacia

Preliminary geological and geotechnical characterization of the Sos Enattos ET site

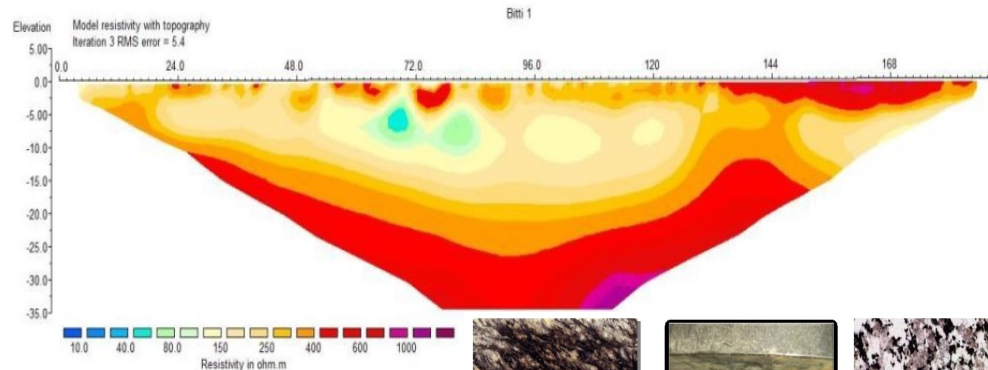
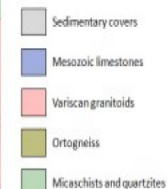
Prof. Giacomo Oggiano

Dr. Stefano Cuccuru

Giugno 2019



Main lithological units:



Horizontal scale is 10.20 pixels per unit spacing
Vertical exaggeration in model section display = 1.00
First electrode is located at 0.0 m.
Last electrode is located at 169.0 m.

Fig. 35. Resistivity tomography of Bitti granite.



Fig. 14: Ortogneiss "Lode type"



Fig. 15: Micaschist after UCS test

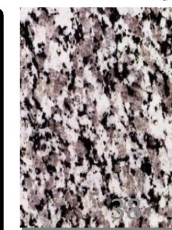


Fig. 16: Granodiorite "Bitti type"